Emergence of Polymer-Coated Corn and Soybean Influenced by Tillage and Sowing Date

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ABSTRACT

No tillage often delays soil warming and drying, thus sowing too early in the spring may compromise seed viability due to prolonged exposure to cold and wet soil in the northern Corn Belt. Coating seed with a temperature-activated polymer may circumvent the adverse effects of exposing seeds to cold and wet soil. Germination and emergence of noncoated and polymer-coated corn (*Zea mays* L.) and soybean [*Glycine max* (L.) Merr.] seed as influenced by tillage and sowing date was examined near Morris, MN. Conventional and no tillage plots were split to accommodate early and late sowing-date treatments while sowing-date plots were split to accommodate seed coat treatments. Near-surface soil water content and temperature, seed germination, and seedling emergence were monitored in 2000, 2001, and 2002. Germination of corn and soybean was delayed by as much as 6 and 11 d, respectively, as a result of sowing polymer-coated vs. noncoated seed. This delay was also evidenced by polymer-coated seed requiring more thermal time (>200°C h for corn and >1000°C h for soybean) to germinate and emerge than noncoated seed. Tillage, sowing date, and seed coating had little influence on plant population of corn. Sowing date and seed coating, however, influenced plant population of soybean in 2 out of 3 yr of this study. We surmise that polymer-coated soybean seed produced a poorer stand as a result of exposure of the hypocotyl to lethal soil temperatures during emergence. This study suggests that temperature-activated polymer coatings delay germination and emergence of corn and soybean.

Weather and the physical state of the soil in early spring pose challenges for the timely establishment of crops in the northern U.S. Corn Belt. Indeed, occurrence of snow or rain or soils that are frozen, snow-covered, or wet in early spring often delays sowing. Sharratt (2002a), for example, reported that soils were covered with snow until mid-April or remained frozen until mid-May in west central Minnesota. Early establishment of crops, however, is critical for achieving maximum grain yield. Buaha et al. (1995) and Lauer et al. (1999) report that corn yield is reduced by 1 to 2% per day as sowing is delayed during May in Minnesota and Wisconsin. Therefore, a limited opportunity exists for establishing crops in spring in the northern Corn Belt.

Early season soil moisture and temperature can be influenced by tillage practices in the northern U.S. Corn Belt. Johnson et al. (1984) and Johnson and Lowery (1985) found that soils subject to no tillage vs. conventional (moldboard plow) tillage were colder and wetter in early spring in Wisconsin. In a subsequent study, Al-Darby and Lowery (1987) found differences in soil temperature among tillage treatments largely influenced germination and emergence of corn. They found that no tillage suppressed soil temperatures and thus delayed emergence of corn by 2 to 8 d as compared with conventional tillage. Wet soils, however, may also hinder germination and emergence in the early spring. For example, seeds may imbibe water but not germinate when exposed to cold and wet soil. Prolonged exposure to microbes that are active in wet soils at temperatures below those required for germination can weaken the seed and cause poor stand establishment (Ford and Hicks, 1992; Shaw, 1977).

Polymer coatings are used in the agriculture seed industry to improve hybrid corn production and for relay cropping (Lessiter, 2000). In addition, polymer-coated seed offers the possibility of extending the growing season of spring crops in cold regions by sowing seed in winter or earlier in the spring (Gesch and Archer, 2005; Peltonen-Sainio et al., 2006). Temperature-activated polymers change structure at a critical temperature; this change in structure also causes a change in permeability of the polymer (Hicks et al., 1996). Thus, polymer coatings can be designed to inhibit water absorption until a critical temperature is attained in the soil. Gesch and Archer (2005) examined the performance of polymer-coated seed in response to sowing date of corn in the northern U.S. Corn Belt. They found that although polymer-coated seed did not consistently delay emergence, stands established using polymer-coated seed typically had higher plant populations as compared with noncoated seed.

Polymer-coated seed has been promoted as a technology that will allow crops to be sown earlier in the spring in cold regions (Lessiter, 2000; Grooms, 2001). This technology may also be beneficial to those who utilize no-tillage practices. Since soils are typically cooler and wetter under no tillage, polymer-coated seed could potentially reside in the soil for a longer time without compromising seed viability, plant populations, or yield. The objective of this study was to ascertain whether polymer-

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Abbreviations: T_b, base temperature; TDR, time domain reflectometry; TT, soil thermal time.

coated seed influences germination and emergence of corn and soybean grown under conventional-tillage and no-tillage practices in the northern Corn Belt.

MATERIALS AND METHODS

This study was conducted on a Barnes loam (fine loamy, mixed, superactive, frigid Calcic Hapludolls) at the University of Minnesota West Central Research and Outreach Center located near Morris, MN (45°36′ N, 95°54′ W). Morris lies at the northern edge of the U.S. Corn Belt where corn is grown continuously or in rotation with soybean, or soybean and wheat (*Triticum aestivum* L.). This region is typified by a subhumid climate with a mean annual air temperature of 5.5°C and annual precipitation of 600 mm. There are 220 d between the last freeze in the spring (8 May) and first freeze in the autumn (28 September).

Tillage and Crop Management

Tillage, sowing date, and polymer seed-coat treatments were applied to experimental plots that were established in 1978 for the purpose of examining the effect of tillage and crop rotation on crop production. Only conventional-tillage and no-tillage plots that had been in a corn–soybean and soybean–corn rotation for the previous 22 yr were used in this study. Our experimental design was a randomized complete block split-split plot with four replications. Tillage was the main treatment with main plots split to examine the effect of sowing date and sowing date plots split to test the effect of seed coating on germination and emergence. Individual plots were 5 by 9 m. Conventional tillage consisted of moldboard plow in autumn and disk harrow before sowing in spring. Plots managed using no tillage remained undisturbed other than the disturbance that occurred as a result of sowing and harvest. Fertilizer and post-emergence herbicides were applied to plots by hand. Plots were fertilized before spring tillage or sowing; plots sown to corn received 168 kg N ha^{-1}, 39 kg P ha^{-1}, and 39 kg K ha^{-1} whereas plots sown to soybean received 8 kg N ha^{-1}, 39 kg P ha^{-1}, and 39 kg K ha^{-1}.

Crops were sown earlier or later than was typical of practices used by growers in the area each year. In 2000, corn was sown on 22 March and 1 May whereas soybean was sown on 1 April and 15 May. In subsequent years, both corn and soybean were sown on 1 May and 14 May 2001 and on 23 April and 16 May 2002. Corn and soybean were sown at a depth of 50 mm in 0.76 m rows at respective populations of 75,000 and 470,000 seeds ha^{-1}.

Seed coating treatments consisted of noncoated and polymer-coated seed. Temperature-activated polymer coatings were applied to Fielders Choice corn hybrid 9198 and Hubner Seed soybean variety H323 by Landec Ag (Menlo Park, CA). Seed was treated with a mix of Captan (*N*-(trichloromethylthio) cyclohex-4-ene-1,2-dicarboximide), Thiram (tetramethylthiuram disulfide), and Metalaxyl (methyl *N*-(methoxyacetyl)-*N*-(2,6-xylyl)-DL-alaninate) before coating with the polymer. Approximately 30 and 20 g of polymer were applied to 1 kg of corn and soybean seed, respectively. New corn seed with a germination of >98% and soybean with a germination of >85% were received each year of this study. Following sowing, surface biomass samples were collected from conventional-tillage and no-tillage corn and soybean plots. Aboveground standing and prostrate crop residue was collected from an area of 0.25 m^2, oven-dried, and weighed.

Seed germination and seedling emergence were monitored in each plot every 2 to 3 d until there was no subsequent change in the number of seeds germinated or seedlings emerged. Germination was ascertained by excavating and examining five seeds in two seed rows. In this study, germination occurred when the radical was visually observed to protrude the seed coat. Emergence was determined by counting the number of coleoptiles or hypocotyls that protruded above the soil surface from two adjacent, 4-m long seed rows. These rows were flagged such that plant counts were obtained from the same area on subsequent sample dates. Percentage germination or emergence was calculated by dividing the number of seeds germinated by the number observed or number of seedlings emerged by the final plant population.

Soil Water and Temperature

Soil water content and temperature were measured within the seed row. Sensors were installed on the same day that the seed was sown. Soil water content was determined using gypsum blocks (Delmhorst Instrument Co., Towaco, NJ) that had been previously calibrated in the laboratory. Calibration of the blocks was performed each year by burying the blocks in a soil container filled with Barnes loam collected at the field site. Water content of the soil in the container was measured by time domain reflectometry (TDR). Upon burying the gypsum blocks and TDR probes at a depth of 50 mm, the soil was wetted and container sealed. The resistance of blocks was monitored every 24 h and recorded when readings stabilized. The container was then uncovered and soil allowed to dry. After sufficient drying, the container was sealed and resistance of blocks monitored every 24 h until stable. This procedure was repeated to obtain block resistance at a range of soil water content (saturation to air dry). A calibration curve of water content vs. resistance was then generated for each gypsum block. One gypsum block was installed at a depth of 50 mm in the seed rows used to ascertain emergence. Soil core samples (50-mm diam) were collected from conventional-tillage and no-tillage plots sown to corn and soybean to assess water retention characteristics within the seed row. Saturated samples were desorbed on a ceramic plate at pressures of 10, 30, 100, and 1500 kPa.

Soil temperature was measured with thermocouples installed at depths of 10, 50, and 100 mm below the soil surface. Three thermocouples, located in the seed rows used to ascertain emergence, were wired in parallel for acquiring a spatially averaged temperature at each depth. Resistance of gypsum blocks was measured and recorded hourly whereas soil temperature was measured every 60 s and recorded hourly using a datalogger.

Soil thermal time (TT) is used to describe the thermal requirement for plant development and was computed as the cumulative difference between hourly soil temperature (50-mm depth) and base temperature (T_b) from the time of sowing. For this study, we assumed that T_b was 10°C. Although activation of the polymer begins at a temperature of about 12°C (Gesch and Archer, 2005), growth of corn and soybean begins at about 10°C (Holmberg, 1973: Major et al., 1975; Shaw, 1977;

Zhang et al., 2001). Soil TT to attain 100% germination and emergence was ascertained from a sigmoidal function used to describe the relationship between percentage germination or emergence (Y) and TT. The function was of the form:

$$Y = 1/(a + be^{-\mathrm{TT}}) \quad [1]$$

where a and b are model parameters obtained by nonlinear regression.

Statistical Analysis

Differences in germination and emergence, soil temperature, and soil TT were tested using ANOVA at a 0.05 probability level. In the event that treatment means were different, Duncan's Multiple Range Test was used to separate treatment means. These tests were performed using CoStat statistical software.

RESULTS AND DISCUSSION

Germination and emergence of corn and soybean occurred under climatic conditions that were warmer than the 30-yr normal in 2000 and colder than normal in 2002. In 2000, temperatures during March and May were, respectively, 6.5 and 2.0°C above normal. In 2001 and 2002, air temperatures during March were at least 4.0°C colder than normal. The unusually cold weather of 2002 extended into April and May with air temperatures at least 1.5°C below normal. Precipitation was at least 20 mm below normal in April 2000, March 2001, and May 2002 whereas precipitation was >50 mm above normal in April and June 2001.

Late spring frosts (daily minimum air temperatures <0°C) did not affect stand establishment in 2000 or 2001. In 2000, the last frost of the spring occurred on 21 April, which was during or after germination but before emergence of early-sown corn and soybean. Frost did not occur after sowing corn and soybean in 2001. In 2002, the last frost of the spring occurred on 24 May, which was after initiation of emergence of early-sown corn and soybean but before initiation of emergence of late-sown corn and soybean.

Soil Water and Temperature

Soil temperature was affected by tillage treatments. Soil was warmer when subject to conventional tillage rather than no tillage (Fig. 1). Averaged across seed coat treatments, soil temperature at a depth of 50 mm in conventional and no tillage from the time of sowing to emergence of early-sown corn was, respectively, 9.4 and 8.5°C (LSD = 0.2°C) in 2000, 16.6 and 16.0°C in 2001, and 12.6 and 11.9°C (LSD = 0.4°C) in 2002. Soil subject to conventional tillage was warmer as a result of higher daily maximum temperatures. Indeed, the average daily maximum 50-mm soil temperature in conventional and no tillage from the time of sowing to emergence of early-sown corn was, respectively, 13.6 and 12.6°C (LSD = 0.6°C) in 2000, 22.2 and 20.8°C (LSD = 0.5°C) in 2001, and 18.0 and 16.8°C (LSD = 0.4°C) in 2002. Differences in soil temperature between conventional and no tillage treatments were even greater after sowing soybean. For example, the difference in average daily maximum 50-mm soil temperature between conventional and no tillage from the time of sowing to emergence of early-sown soybean was 1.4°C in 2000, 2.1°C in 2001, and 1.8°C in 2002. Soil subject to conventional tillage was presumed warmer as a result of enhanced radiation absorption under lower crop residue loadings on the soil surface (Horton et al., 1996; Sharratt, 2002b). Indeed, averaged across the 3 yr of this study, crop residue remaining on the soil surface in conventional-tillage and no-tillage treatments was, respectively, 150 and 7200 kg ha^{-1} after sowing soybean (residue remaining after the previous year corn crop) and 50 and 2900 kg ha^{-1} after sowing corn (residue remaining after the previous year soybean crop).

Although conventional tillage reduces surface biomass and exposes more of the soil surface to solar radiation and the forces of wind, we found no consistent difference in soil water content between conventional-tillage and no-tillage corn or soybean across years. In fact, soil water content at a depth of 50 mm during much of the time from sowing to emergence was similar for conventional-tillage and no-tillage corn or soybean (Fig. 2). Soil water content remained near 0.40 m^3 m^{-3} from sowing to emergence over the 3 yr of this study, except during

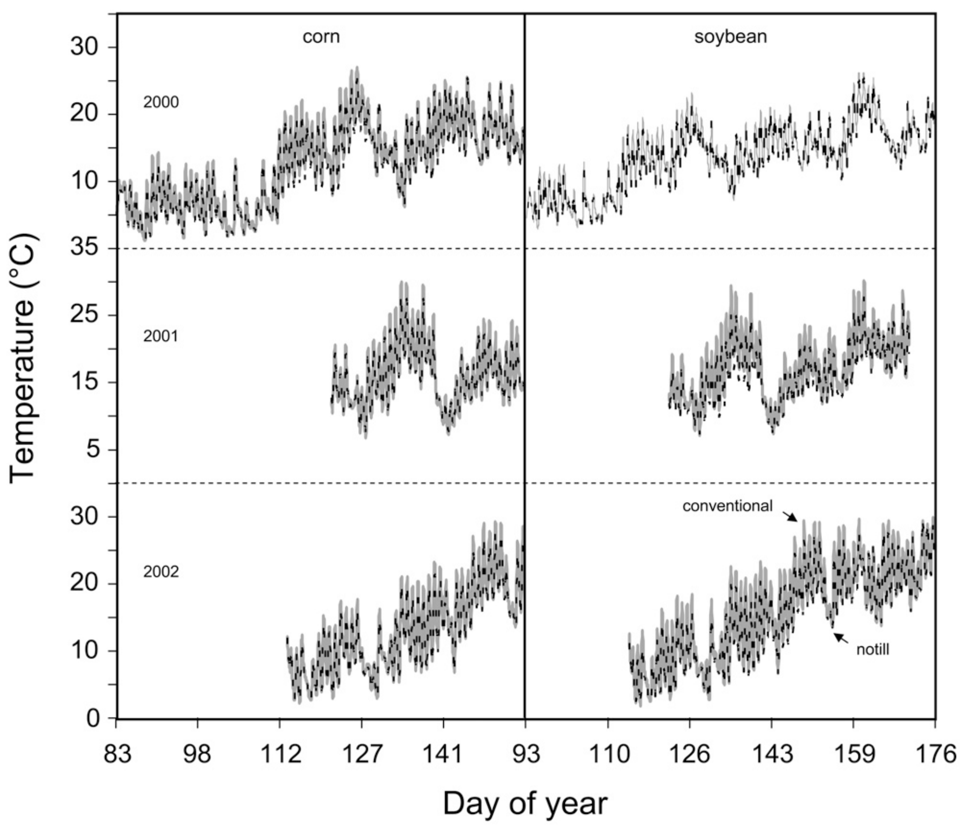

Fig. 1. Hourly soil temperature at the 50-mm depth of early-sown corn and soybean as influenced by conventional-tillage and no-tillage over 3 yr at Morris, MN.

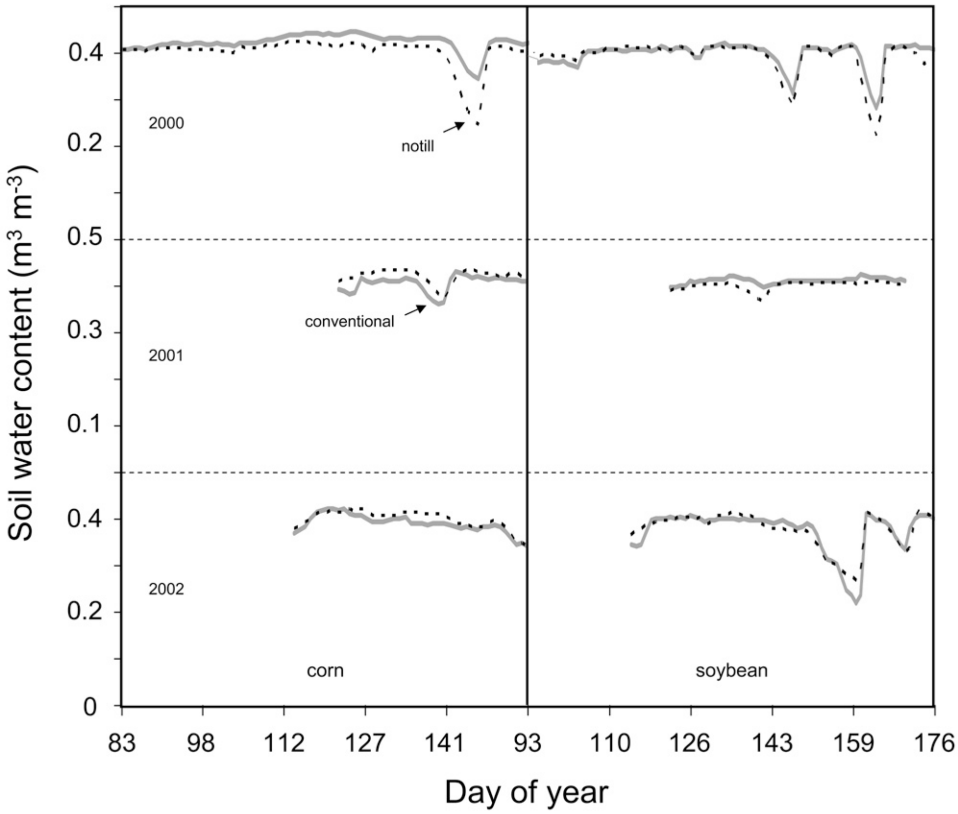

Fig. 2. Hourly soil water content at the 50-mm depth of early-sown corn and soybean as influenced by conventional-tillage and no-tillage over 3 yr at Morris, MN.

occasional warm and dry periods. For example, soil water content under conventional and no tillage, respectively, dropped to 0.35 $m^3\ m^{-3}$ (–10 kPa matric potential or 75% saturation for Barnes loam) and 0.25 $m^3\ m^{-3}$ (–50 kPa potential) for early-sown corn and to 0.32 and 0.29 $m^3\ m^{-3}$ for early-sown soybean on 26 May 2000 after 11 d with no precipitation and air temperatures that averaged 16.2°C. Likewise, soil water content of early-sown soybean declined to 0.22 $m^3\ m^{-3}$ (–100 kPa matric potential) in conventional tillage and to 0.27 $m^3\ m^{-3}$ (–30 kPa matric potential) in no tillage on 9 June 2002 (Fig. 2) after 12 d with little precipitation (3 mm over those days) and air temperatures that averaged 20.3°C. Precipitation occurring after these warm and dry periods resulted in a subsequent rise in soil water content. Had the above difference in soil matric potential between tillage treatments persisted from sowing to emergence of early-sown corn in 2000, the Schneider and Gupta (1985) emergence model suggests that emergence of early-sown corn would have been delayed under no tillage by 3.3 and 1.5 d at respective soil temperatures of 10 and 15°C. However, lack of any persistent or consistent difference in soil water content between tillage treatments would likely have little or no effect on germination and emergence. In fact, soil water content of conventional tillage and no tillage treatments appeared near optimal for emergence over the 3 yr of this study.

Germination and Emergence

Differences in soil temperature across years affected germination and emergence of corn and soybean. Averaged across all treatments, germination of corn required 10.9, 5.8, and 10.6 d while germination of soybean required 16.6, 10.6, and 16.0 d in successive years. Likewise, emergence of corn required 29.0, 14.8, and 27.1 d while emergence of soybean required 32.5, 32.5, and 43.9 d in 2000, 2001, and 2002, respectively. The slower germination and emergence of corn and germination of soybean in 2000 and 2002 was associated with colder soil temperatures as compared with soil temperatures in 2001. Emergence of soybean, however, appeared to be hastened after germination in 2000. Rapid emergence of germinated soybean, which largely occurred during May, was caused by above normal temperatures during May 2000.

Germination of corn and soybean was delayed as a result of sowing polymer-coated vs. noncoated seed in all years. For example, averaged across tillage and sowing date treatments, germination of polymer-coated corn seed was delayed 6, 4, and 2 d while germination of polymer-coated soybean seed was delayed 11, 10, and 9 d in successive years. The delay in germination also retarded emergence, but the delay in emergence equaled the delay in germination for corn. For soybean, however, the difference in days to emergence between seed coat treatments was smaller than the difference in days to germination. For example, averaged across tillage and sowing date treatments, germination of noncoated and polymer-coated soybean seed required 11 and 22 d in 2000, 6 and 16 d in 2001, and 11 and 20 d in 2002 while emergence of noncoated and polymer-coated soybean seed required 30 and 34 d in 2000, 30 and 35 d in 2001, and 41 and 47 d in 2002. These observations suggest that the hypocotyl develops and emerges more rapidly or uniformly for the polymer-coated than noncoated soybean seed treatment in this study.

Soil thermal time required for germination of corn and soybean was influenced by sowing date and seed coating treatments in all years (Table 1). Corn and soybean sown earlier rather than later in the spring required less thermal time to germinate. For example, averaged over the 3 yr of this study, corn sown earlier and later in the spring required 270 and 890°C h to germinate, whereas soybean sown earlier and later in the spring required 635 and 1585°C h to germinate. Early-sown corn and soybean did not require as much thermal time to germinate, likely as a result of early-sown seeds being exposed to and developing under more frequent suboptimal soil temperatures (temperatures below T_b) as compared with late-sown seeds. Thermal time was computed using a 10°C T_b and thus any development occurring below this temperature threshold did not contribute to accumulated thermal time. Noncoated seed also required less thermal time to germinate than polymer-coated seed. Averaged over 3 yr, noncoated and polymer-coated corn seed required 345 and 815°C h to germinate, whereas noncoated and polymer-coated soybean required 365 and 1855°C h to germinate. Noncoated seed required less thermal time to germinate as a result of developing at soil temperatures below that required for initiating metamorphosis of the polymer-based coating (about 12°C).

Although the thermal requirement for germination of corn and soybean was influenced by sowing date during the 3 yr of this study, the thermal requirements for emergence of soybean was only influenced by sowing date in 2000 and 2002 whereas the thermal requirements for emergence of corn was only influenced by sowing date in 2000 (Table 1). Thus, there was a tendency for differences in the thermal requirements to germinate early-sown and late-sown seed to extend into the seedling emergence phase of development. Differences in the thermal requirements to germinate noncoated and polymer-coated seed, however, extended into the seedling emergence phase of corn and soybean during all 3 yr of this study. Emergence of noncoated seed required less thermal time than emergence of polymer-coated seed.

Tillage influenced germination of corn and soybean, but not across all years of this study (Table 1). In years when tillage influenced germination, less thermal time was required to germinate corn and soybean under no tillage than conventional tillage. Since no tillage resulted in colder soils in this study, germination of corn and soybean likely proceeded at temperatures below the base temperature (no accumulation of thermal time). While the effect of tillage on the thermal requirement for germination of soybean extended into the emergence phase of development, the thermal requirement for the emergence of corn was not affected by tillage. This apparent lack of effect of tillage on emergence of corn may be due to the impact of crop rotation on soil temperature (i.e., less surface residue due to previous soybean crop). Tillage likely affected germination and emergence of soybean more than corn due to larger differences in soil temperature between conventional and no tillage in plots sown to soybean.

Thermal time requirements for germination and emergence of both corn and soybean in 2000 exhibited a seed coat × tillage as well as seed coat × sowing date interaction. A seed coat × tillage interaction was also apparent for thermal time to germination and emergence of soybean in 2001 while a seed coat × sowing date interaction was found for thermal time to germination and emergence of corn in 2001 and soybean in 2002. These interactions suggested that differences in soil TT between tillage or sowing date treatments were smaller for noncoated seed than for polymer-coated seed.

Plant Population

Seed coating did not affect stand establishment of corn in any year of this study (Table 2). Gesch and Archer (2005) observed that seed coating affected stand establishment of Fielder's Choice hybrid 9198 (same hybrid as used in this study), but only in one out of 3 yr of their study. They found that stand establishment was influenced by hybrid, weight of polymer coating applied to the seed, and sowing date. Sowing date influenced stand establishment of corn in our study, but only in 2002 when plant population was greater for corn sown later in the spring. Delayed sowing was beneficial to establishment of corn under the unusually cold spring of 2002. Gesch and Archer (2005) also found that delayed sowing in the spring resulted in higher plant populations, but differences were not apparent in all years. Tillage did not affect plant population of corn in any year of this study.

Stand establishment of soybean was influenced by seed coating in two out of 3 yr of this study with polymer-coated seed resulting in poorer stands as compared with noncoated seed (Table 2). Delayed emergence of polymer-coated soybean seed possibly exposed the emerging hypocotyl to soil temperatures that were near lethal (40°C) later in the spring. Indeed, Hatfield and Egli (1974) found that elongation of the hypocotyl was suppressed by soil temperatures >30°C with complete failure for the hypocotyl to develop at temperatures of 40°C. Differences in exposure of the hypocotyl of noncoated and polymer-coated seed to extreme near-surface (10-mm depth) soil temperatures are illustrated for late-sown soybean. Averaged across tillage treatments in 2000,

Table 1. Soil thermal time required to attain 100% germination and emergence of soybean and corn as influenced by tillage, sowing date, and seed coating over 3 yr at Morris, MN.

Crop	Treatment		Thermal time					
			Germination			Emergence		
			2000	2001	2002	2000	2001	2002
			°C h					
Corn	tillage	conv†	573b§	753	496	1947	2046	2593
		no	452a	751	454	1906	2109	2674
	sowing date‡	early	44a	539a	226a	1702a	2067	2630
		late	981b	965b	724b	2151b	2088	2638
	seed coating	none	204a	464a	365a	1672a	1712a	2329a
		polymer	821b	1040b	584b	2181b	2443b	2938b
Soybean	tillage	conv	1091b	1365b	1186	4035b	5079b	7408
		no	855a	1108a	1049	3507a	4347a	6750
	sowing date	early	388a	1081a	438a	2607a	4630	6240a
		late	1559b	1392b	1798b	4937b	4796	7918b
	seed coating	none	148a	479a	468a	3091a	4053a	6006a
		polymer	1799b	1995b	1768b	4451b	5373b	8152b

† Conventional tillage.

‡ Sowing dates in 2000: early corn, 22 March; late corn, 1 May; early soybean, 1 April; late soybean, 15 May; 2001: early corn and soybean, 1 May; late corn and soybean, 14 May; 2002: early corn and soybean, 23 April; late corn and soybean, 16 May.

§ Mean separation within columns by Duncan's multiple range test. Means followed by different letters within each treatment are significantly different at $P \leq 0.05$.

Table 2. Plant population of soybean and corn as influenced by tillage, sowing date, and seed coating during 3 yr at Morris, MN.

Crop	Treatment		Population		
			2000	2001	2003
			plants m^{-2}		
Corn	tillage	conv†	5.6§	6.3	6.1
		no	5.4	6.6	6.1
	sowing date‡	early	5.1	6.4	5.7a
		late	5.8	6.6	6.5b
	seed coating	none	5.4	6.3	5.8
		polymer	5.5	6.6	6.4
Soybean	tillage	conv	33.3b	32.5	34.6
		no	29.2a	31.6	28.9
	sowing date	early	31.8	30.3a	33.9b
		late	30.7	33.9b	29.6a
	seed coating	none	33.0b	32.6	36.1b
		polymer	29.6a	31.6	27.3a

† Conventional tillage.

‡ Sowing dates in 2000: early corn, 22 March; late corn, 1 May; early soybean, 1 April; late soybean, 15 May; 2001: early corn and soybean, 1 May; late corn and soybean, 14 May; 2002: early corn and soybean, 23 April; late corn and soybean, 16 May.

§ Mean separation within columns by Duncan's multiple range test. Means followed by different letters within each treatment are significantly different at $P \leq 0.05$.

the emerging hypocotyl (period between protrusion of radicle from seed coat to projection of hypocotyl above soil surface) of noncoated seed was not exposed to 10-mm soil temperatures that exceeded 40°C, but the hypocotyl of polymer-coated seed was exposed to soil temperatures that exceeded 40°C on 2 d. Daily maximum 10-mm soil temperatures ranged from 15.2 ± 0.6 to 37.7 ± 1.9°C and 15.6 ± 1.9 to 39.5 ± 2.0°C during emergence of the hypocotyl of noncoated and polymer-coated seed, respectively, in 2000. In 2001, the average daily maximum 10-mm soil temperature during emergence of the hypocotyl was higher for polymer-coated (26.6°C) vs. noncoated (23.8°C) seed (LSD = 2.0°C). However, the daily maximum soil temperatures did not exceed 40°C in either seed coat treatment. Averaged across tillage treatments in 2002, the emerging hypocotyl of noncoated and polymer-coated seed was exposed to 10-mm soil temperatures that exceeded 40°C on 6 d. The hypocotyl of polymer-coated seed, however, was exposed to more extreme soil temperatures. For example, the extreme temperature occurring during emergence of the hypocotyl was 44.9 and 49.7°C (LSD = 3.8°C) for noncoated and polymer-coated seed.

Sowing date influenced plant population of soybean in the latter 2 yr of this study, but the effect of sowing date on stand establishment was not consistent between years. More plants were established as a result of sowing later in the spring in 2001 and earlier in the spring in 2002. We are uncertain as to the cause of this effect, other than emerging seedlings of late-sown soybean encountered higher soil temperatures than early-sown soybean in 2002 (Fig. 1). Tillage did affect plant population of soybean. Plant population was higher when soybean was grown under conventional tillage rather than no tillage in 2000; this trend for higher plant population in conventional tillage also was apparent in subsequent years.

CONCLUSIONS

Early establishment of crops is required to achieve maximum production in the northern U.S. Corn Belt. Indeed, corn yields decline if sowing is delayed past 1 May in Minnesota and Wisconsin. Soils can be frozen, cold, or wet in late April and early May and no tillage may exacerbate these conditions in the northern Corn Belt. Seed coated with a temperature-activated polymer may allow early sowing and prolonged exposure in cold and wet soil without jeopardizing seed viability or stand establishment. While polymer-coated seed delayed germination and emergence of soybean and corn, we found no adverse effect of this delay on stand establishment of corn. However, delayed germination of soybean resulted in poor establishment in some years due to exposure of the emerging hypocotyl to high soil temperatures. Polymer-coated soybean seed also demonstrated a more rapid or uniform emergence as compared with noncoated seed.

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